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A GAS-FIRED KILN FOR HOME AND STUDENT POTTERS

by

Ervin Lee Van Haaften

Approved by Committee:

Condon Kuhl
Chairman

John M. Hicks

Earle L. Canfield
Dean of the Graduate Division

A GAS-FIRED KILN FOR HOME
AND STUDENT POTTERS

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CHAPTER I

INTRODUCTION

To discover the properties and characteristics of clays, colors, and glazes, and their interdependent reaction to heat, to regulate and control them, to make a thing of beauty and utility from his knowledge and skill--this is the goal of the artist potter. This should also be the incentive held before the student potter. The experience of experimenting with, and adjusting to, the result of fire's effect upon clay is too often left completely to the instructor or even made non-existent by some automatic device.

This experience is especially valuable when reduction occurs during the firing cycle. Although reduction firing is a very old process, dating back to the Sung and Ming dynasties in China, relatively few amateur or student potters today have access to a kiln in which a reduction atmosphere can be maintained.

What is reduction firing? When a combustible material is ignited, it burns in a normal oxidizing atmosphere as long as it receives enough oxygen to burn brightly and efficiently, but if the fuel does not get enough air, it smokes and chars, giving off an excess of carbon. In a kiln chamber, this may be brought about in one or both of two ways. The kiln dampers may be partially closed at the flue, or the air intake may be partially cut down at each burner.

Why is reduction firing at times desirable? Carlton Ball described aptly and concisely the end and the means of the reduction process:

> In its hunger, the flame heating the reduction firing seeks oxygen from any possible sources--even the pottery itself. The carbon in the kiln has such a strong affinity for oxygen that it actually draws it from the materials in the clay and glaze. . . . Because some of the oxygen is removed from these elements in clay and glaze, their color changes. And when these changes are controlled to achieve a desirable effect, the pots fired in a reduction kiln can be most unusual and beautiful.[1]

Reduction firing has in past centuries been the common experience of the professional and student potter, since in most kilns using a combustible material as a heat source, at least a slight amount of reduction occurs naturally, in spite of precautions taken against it. The advent of the electrical element, as a source of heat, has brought about the large-scale distribution of low-cost kilns. Today, pottery is a relatively inexpensive avocation for the home ceramist, and simple, practically automatic firing pro-

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[1]F. Carlton Ball, "An Introduction to Reduction Firing," Ceramics Monthly, XII (February, 1964), 32.

cedures have made possible the widespread use of kilns in the public schools. The use of electricity has also almost completely eliminated the possibility of reduction during the firing. In an electric kiln, reduction is not accomplished practically, since the electrical element does not consume oxygen, and introducing carbon has a harmful effect upon the elements.[1] These same factors, low initial cost and ease of operation, have tended to discourage the use of kilns that are designed to produce heat with a combustible material, of which gas is, by far, the most common and usually the most practical type used in this country. As a result, the average home or student potter has no opportunity to experiment with the reduction process.

The writer, for this reason, chose to study the possibilities for designing and constructing a gas-fired kiln having a low initial cost, that would be easily adjusted and altered as the construction developed, as well as after some experimenting was done with the firing of the unit. It was to be designed in such a way that it could easily be con-

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[1]The use of pine splinters, moth balls and other combustible materials inserted into a hot electric kiln has been tried with a very limited amount of success, but it is advised against by electrical element manufacturers. For additional information see: Glenn C. Nelson, Ceramics (New York; Holt, Rinehart, and Winston, Inc., 1960), p. 177.

structed in a home or school workshop. Since many potters prefer to work with stoneware, an attempt would be made to design an appliance that could withstand temperatures of 2300 degrees.

This problem was first brought to the writer's attention by Bill Farrell of the department of art and design at Purdue University, Lafayette, Indiana. At a meeting of art educators, he proposed that instructors sensitize their students to the properties and potentialities of clay to a much greater degree than has been tried in the past, particularly in the area of firing procedures.[1]

An investigation of the cost of commercial gas-fired kilns showed that even small (two cubic feet) ones were far more expensive than the average school's art fund or average home potter's budget would allow. A study of materials available for constructing a kiln revealed that a number of recently developed light-weight insulative products could be used advantageously, and that they would cut expenses considerably, in comparison with commercial kilns, which are usually designed for production operations. After other costs were estimated and the facilities for construction were evaluated, the project was begun.

[1]Opinion expressed by Bill Farrell at the Western Arts Association convention, Minneapolis, Minnesota, March 25, 1964.

CHAPTER II

MATERIALS

The materials chosen and the design of the kiln were often mutually dependent, but the materials were, in most cases, the determining factor. Thermal stability was basic in the choice of most materials.

Refractory lining. The first material obtained was the refractory lining. A light-weight firebrick was chosen, both for insulative qualities and for ease of cutting and shaping. Of the brick studied with a temperature rating of around 2300 to 2400 degrees Fahrenheit, two types seemed particularly well-suited to the need at hand. One was made of refractory clays and the other of diatomaceous silica.[1] Although the silica type was cheaper and had a greater crush strength rating, the clay type was chosen because of its lighter weight, lower heat conductivity, and higher transverse strength rating. The lower amount of heat loss through the lining wall not only afforded better protection for the back-up material, but cut fuel consumption as well. Since the kiln was to be quite small, and brick damage would not

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[1]Specific data may be obtained from ceramic materials manufacturers and suppliers. See list on page 15.

occur from pressure or compression of weight, it is readily seen that transverse strength was a more important factor than crush strength. The brick used were easily cut on a common table saw. At the lecture previously mentioned, Mr. Farrell suggested that using a tongue-and-groove type of construction would eliminate the need for mortaring the brick.[1] This interlocking, but somewhat flexible arrangement seemed to be an excellent means of allowing for adjustment and alteration.

Back-up material. A refractory material can usually be manufactured with better insulative qualities at the expense of losing some of its heat resistance; therefore a back-up wall, less heat resistant, but more insulative, is usually placed around the inner wall. Of the insulations available for use as back-up material, only a few were considered adequate for the project. Some were available in unsuitably small thicknesses. Others did not have the necessary refractory qualities to withstand continuous exposure to high temperatures. The number was narrowed down to two blanket-types, a Johns-Manville product, Cerafelt, and a Carborundum Company product, Fiberfrax. The latter

[1]Opinion expressed by Bill Farrell at the Western Arts Association convention, Minneapolis, Minnesota, March 25, 1964.

product has excellent refractory qualities, and is manufactured without the use of organic binders. Cerafelt, although it was found to have a thermal stability rating slightly lower than that of the Fiberfrax and does contain a small amount of organic binder, was considerably cheaper and is available in a much wider range of thicknesses. Because of these two factors, the Johns-Manville product was chosen. It has a heat resistance rating of 2000 degrees under continuous exposure, and contains no corrosive promoting agents.[1] Its availability in thicknesses up to two inches was an important factor, because this back-up area was designed to use a somewhat spongy material that could be slightly compressed without greatly affecting its density. It was to be resilient, acting as a buffer between the expanding and contracting inner wall and the practically stable outer shell.

Shell. The metal shell was designed to fit neatly around the sides of the structure. Galvanized twenty gauge sheet metal was found to be a sufficiently sturdy material for the purpose, and this self-containing design eliminated the need for external framework other than the supporting angle iron frame.

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[1]More data on this and other refractory products may be obtained from ceramic materials manufacturers and suppliers. See list on page 15.

Frame. The supporting frame was designed to retain the walls at the bottom, and to raise the chamber so that a burner could be mounted beneath it. This also made allowance for air circulation beneath the chamber. The angle iron was purchased from a scrap metal dealer at a very nominal cost. A number of different arrangements could easily be constructed, but one limitation should be noted by those intending to use a kiln in an enclosed area. The American Gas Association's standard regulations stipulate that a minimum of six inches of circulating air space be kept between a major heating appliance and any combustible material.[1] Kiln legs should therefore be at least six inches long. The side and center subfloor support irons were spaced approximately seven and one-half inches apart. The short span between these supports made possible the use of a floor support layer of relatively low transverse strength.

Floor and roof supports. A one-half inch sheet of asbestos board was used for the floor support layer. This material is inexpensive and is available in a number of grades. The Johns-Manville Company's C Grade Millboard has

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[1]For additional regulations regarding heating appliances, see the American Gas Association's pamphlet number Z 21.30-1954, or the National Fire Protection Association's booklet number 54.54A.

an especially long grade of asbestos fiber and is suitable for temperatures up to 1200 degrees Fahrenheit. If heated beyond this limit, embrittlement occurs, but when, as in this case, brittleness is not objectionable, the limit is raised to 1800 degrees, well above the requirement for this part of the project.[1]

For the roof support, two kiln shelves were used. This was the only material found that combined enough transverse strength to span the width of the kiln, with refractory properties adequate to withstand direct exposure to the heat at the top of the chamber.

Fuel and burner. The two most practical gas types available, liquid petroleum and natural, were studied and compared. It was found that, although natural gas was, for most purposes, slightly cheaper, the cost was not a very significant factor. Two of the main advantages of liquid petroleum gas are: (1) high available gas pressure at the burner orifice, and (2) the ease of installation and portability of the gas supply. Burners on kilns using natural

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[1]Sales literature provided with the material. Johns-Manville millboard insulating sheet material. Johns-Manville General Headquarters: 22 East 40th Street, New York 16, N. Y.

gas usually require a forced air system in order to achieve a high temperature firing and usually need a larger than normal gas outlet. Gas weight was an important consideration. In the event of a leak or mistakenly left on jet, natural gas, being lighter than air, naturally tends to be vented through windows and air ducts. Liquid petroleum gas is heavier than air. Since it lies near its point of escape, and is not easily moved with room air circulation, it could easily be ignited by a falling match or spark.

Considerations of fuel types also led to a comparative study of exhaust systems and safety devices. Larger kilns at the State College of Iowa, Cedar Falls, Iowa, the State University of Iowa, Iowa City, Iowa and the Des Moines Art Center, Des Moines, Iowa, were examined. These kilns burn natural gas and most are equipped with exhaust hoods. Don Finnigan, pottery teacher at the State College of Iowa, suggested that the writer construct a burner with pieces of pipe and use a squirrel-cage type blower to supply the forced air.[1] This was later done and tested on a normal natural-gas outlet. At about the same time a venturi-type burner was tested using liquid petroleum gas. The two types

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[1]Statement by Donald Finnigan, personal interview, May 21, 1964.

seemed to put forth a flame of about the same length and intensity.

The building in which the kiln was to be fired was a wooden structure. As a safety precaution, as well as for simplicity of design and construction, and for minimizing costs, it was decided that it would be best to fire the kiln out-of-doors. A minimal shelter was needed to give the unit protection from rain and snow, but the cost of this protection proved to be only a small fraction of the cost of safety devices, which the writer felt would have been necessary if the firing were done in the building in which the project was constructed. Of the automatic safety devices investigated, the only type which could be relied upon at the high temperatures planned for the kiln was an electronic flame detector that could close a gas valve through its detection, or rather lack of detection, of the ultraviolet radiation given off by a gas or oil flame, in the event that it were accidentally blown out. The cost of the device was many times that of the rest of the entire project and it was therefore considered no further.

In an out-of-door location, the liquid petroleum gas is relatively safe to use and solves many installation problems. A one hundred pound tank was ordered with a regulator that allowed a useable gas pressure range of from zero to thirty-five pounds. The higher pressure of liquid petroleum gas eliminated the need for a blower on the burner. The burner used was a venturi-type torch made by the Marquette Company of Minneapolis, Minnesota. Any venturi-type burner with a rating of from 300,000 to 500,000 B.T.U. per hour would probably be sufficient to furnish the necessary heat. Clayton Bailey suggested the use of another small burner, the model 70LV Ransome Torch, distributed by the Ransome Torch and Burner Company, Oakland, California.[1] His demonstration with this burner showed that it could have been used equally well for the project.

Flue and raincap. A common stovepipe was used to direct the escaping gases, and to give the kiln enough draft to keep the burner working efficiently. William Ross, potter-instructor at the Des Moines Art Center, was consulted as to the length of pipe needed. He said that in his experience a number of factors, such as the wind velocity and the location of the kiln with respect to nearby buildings and trees, had affected the draft of a flue. He suggested that a firing be first tried with a pipe of a few feet, and

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[1]Statement by Clayton Bailey, pottery instructor at State University of Iowa, personal interview, July 7, 1964.

that, since it is possible to have a flue with too much draft, other sections be added until the flame burned steadily and efficiently.[1] Two sections of pipe, each twenty-four inches long, were used in the first firing. No further adjustment was needed.

To protect the kiln from moisture that might enter the chamber through the flue, an aluminum rain-cap was placed on the top. It collapsed during the first firing, closing off the flue. This caused heavy reduction, and for a time, a great deal of excitement and concern on the part of the writer. It was replaced with a furnace pipe tee-joint, which has held up satisfactorily in subsequent firings.

Shelter. An A-frame type shelter was designed to be constructed over the unit. The outer shell of the kiln was galvanized, but this extra protection helped to keep the kiln from collecting moisture in the insulation layer. Four sheets of corrugated metal roofing, each six feet long, were used to form the self-supporting structure. Small bolts and pieces of wood were used to hold the sheets of roofing together.

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[1]Comment by William Ross, personal interview, June 18, 1964.

<u>Kiln furniture and equipment</u>. Three kiln shelves, in addition to those used for roof supports, were purchased: (1) a full shelf, sixteen inches square, (2) a half shelf, eight inches wide and sixteen inches long, and (3) a small shelf, eight inches square. A variety of shelf supports were ordered, so that the arrangement of contents in the chamber would be quite flexible. A pyrometer was used to check the rate of heat rise. A list of estimated costs of the materials used and a list of suppliers are found on the following two pages.

<u>Estimated cost of materials</u>. An estimate of the cost of the project is given in the following list of materials and their costs:

Kiln materials	Cost
Burner	19.95
Scrap iron	2.00
Bolts	.80
Radiator hose clamp	.15
Asbestos millboard	3.00
Light-weight firebrick	36.00
Kiln shelves	12.00
Back-up material	33.00
Sheet metal (including spot-welding)	18.50
Flue	1.50
Raincap	1.24
Total	128.14

Kiln furniture and equipment	Cost
Kiln shelves	11.95
Shelf supports	2.98
Pyrometer	18.75
Corrugated roofing	5.14
Bolts	1.04
Screws	.18
Total	40.04

The above list does not include shipping or handling costs.

Manufacturers and suppliers. Materials were obtained from the following manufacturers and suppliers:

Material	Manufacturer or supplier
Burner	Marquette Manufacturing Co. 307 East Hennepin Ave. Minneapolis, Minn. 55414
Millboard	Central Asbestos and Supply Co. 317 East Sixth Street Des Moines, Iowa
Firebrick	Johns-Manville 22 East 40th Street New York 16, New York
Kiln Shelves	Parker Ceramics Supply Co. 2204 W. 23rd Street Des Moines, Iowa
Back-up	Johns-Manville
Pyrometer	Parker Ceramics Supply Co.

This list does not include the more common items used, available in most cities and towns.

CHAPTER III

CONSTRUCTION

Throughout the planning stage of the project, simplicity and ease of construction were kept foremost in the designer's purpose. Plans for a rectilinear structure of approximately equal height, width, and depth were laid out in the first sketch. After studying both up-draft and down-draft kilns, a simple up-draft design was developed, since down-draft kilns use baffle walls, and the flue on a down-draft type would have also been somewhat more complicated. To further simplify the design, the doorway was placed in the front, and was to be bricked shut with each firing. This eliminated the need for a door framework or hinge. Since the standard firebrick is nine inches long and four and one-half inches wide, it was decided that, to make good use of these dimensions, the floor of the chamber should be eighteen inches square. The side brick would be placed on edge, adding another two and one-half inches on each side. An additional two-inch layer of insulation would bring both dimensions of the bottom of the kiln to approximately twenty-seven inches. These dimensions determined the size of the frame.

Frame. The frame was constructed of six pieces of angle iron. These were cut to length with a hack saw, and half-inch holes were drilled at the points indicated in Figure 15, using an electric drill press.

Legs. Half-inch holes were cut in the ends of the four metal straps used for legs. These were then bent into the shape shown in Figure 1, and the six frame pieces, together with the legs, were bolted into one solid unit. A small brace, with an adjustable clamp at one end, was used to hold the burner in position.

Burner air-shutter. To control the air intake at the burner orifice, a shutter was devised at the bottom of the burner's throat. A metal ring-shaped platform was brazed to the elbow joint at the base of the burner nozzle. Another piece of metal was bent into a cylindrical shape and slipped over the nozzle, held in place with a radiator hose clamp. Lowering the cylinder down toward the base platform cut the air supply, normally sucked through the burner throat by the escaping gas stream at the orifice. See Figure 2.

Floor support. The asbestos-millboard subfloor, or chamber floor support, was cut to the proper dimensions with

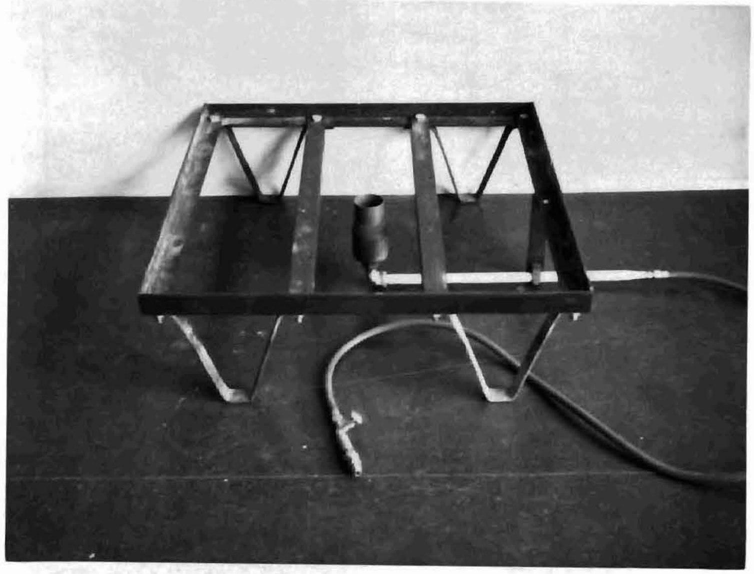


Figure 1. Supporting frame and burner, gas-fired kiln for home and student potters.

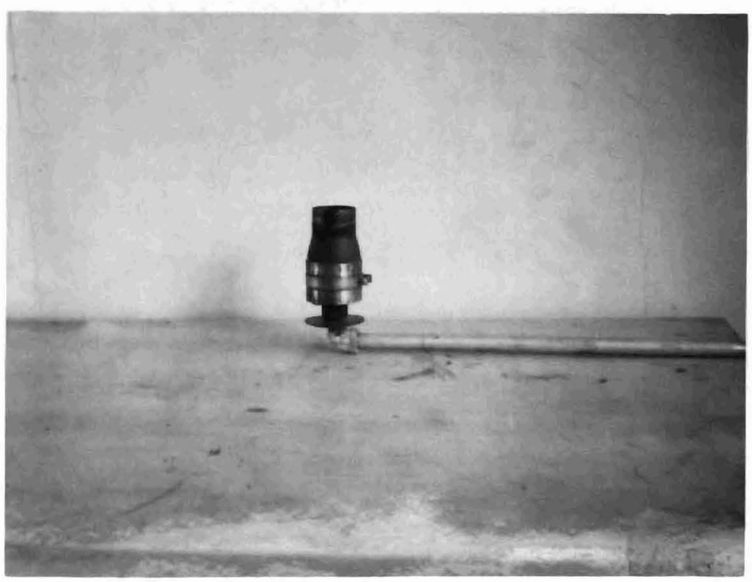


Figure 2. Air shutter, gas-fired kiln for home and student potters.

a hand saw. Using a sharp knife, small indentations were cut out of the bottom side of the sheet, at the points where it would come in contact with the protruding bolt heads of the frame. This allowed the sheet to rest firmly on the side irons and brace irons of the frame. See Figure 14. A three-inch hole for the burner was cut in the center of the sheet.

Floor and walls. As shown in Figure 5, eight brick were laid flat to form the floor of the chamber. A three-inch hole was cut, centered at the point where the four center brick met.

The wall brick were stacked tongue-and-groove, on edge, interlocking at the rear corners of the kiln, as shown in Figures 4, 13, and 14. Tongues and grooves were shaped with the use of a table saw. A dado saw-blade would have shortened considerably the time taken to gut the grooves, but since the brick cut very easily, a common blade worked very satisfactorily. A number of cuts made side by side formed grooves of any desirable width. The groove on the top layer was cut along the inside edge, such that the roof-support shelves could be fully recessed. See Figures 5 and 15.

Roof supports. Two twenty-inch kiln shelves spanned the width of the kiln, resting in grooves along the edge of

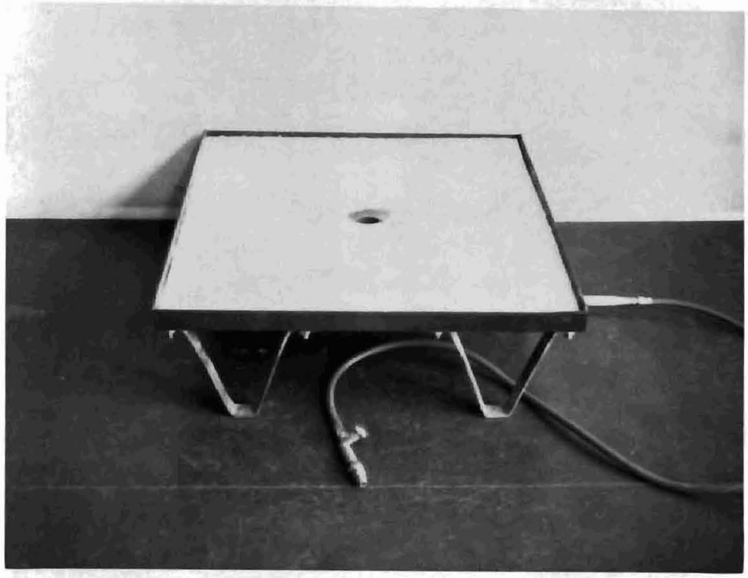


Figure 3. Floor support, gas-fired kiln for home and student potters.

Figure 4. Walls, gas-fired kiln for home and student potters.

the top layer of side and rear brick. A semicircle was cut out at the center of the inside edge of each support, so that a three inch hole was formed for the flue. See Figure 5. The shelves were taken to a stone cutter for this purpose, although, with care, the job could have been accomplished with an unshielded grinding wheel.

Roof. The roof layer was composed of fifteen insulating firebrick, laid flat in three rows of five bricks each. In the center brick a three-inch flue hole was cut with a key-hole saw, after a half-inch hole was drilled in the center. Although the two end brick of each row fell one-fourth inch short of the width of the chamber walls on each side, this difference was insignificant, since the spongy layer of insulation was later pressed into these areas. See Figure 15. The front row of brick completely overlapped the door brick, but the back row of brick was cut shorter, leaving room for the blanket insulation on the back of the kiln.

Back-up material. The blanket insulation was cut, with a large pair of scissors, to fit the sides, rear, and top of the unit. A five-inch square hole was cut in the center of the top layer to allow for the flue hole and its brick liner. See Figure 14.

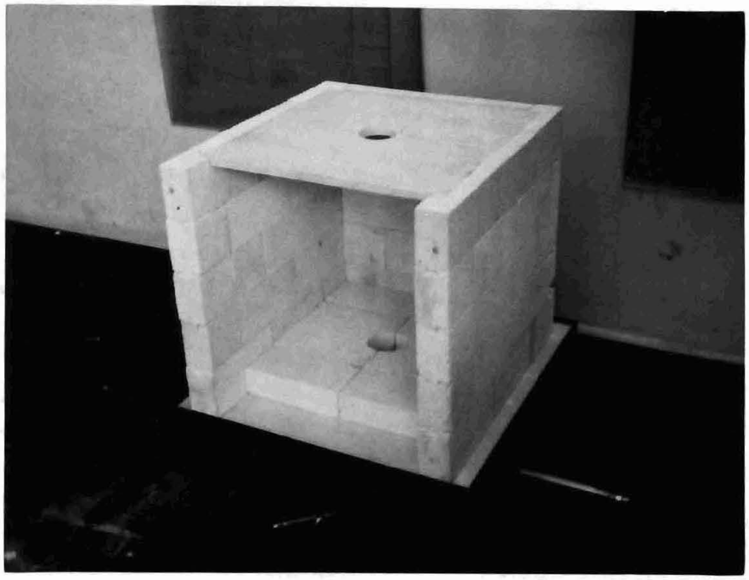


Figure 5. Roof support, gas-fired kiln for home and student potters.

Figure 6. Back-up material, gas-fired kiln for home and student potters.

<u>Shell and door cover</u>. The outer protective and containing shell was cut and folded at a sheet metal establishment, according to the pattern shown in Figure 16. Tabs were left at the corners for spot welding. This gave the cap better containing strength to hold the side, rear, and roof parts firmly in place.

A half-inch hole was drilled in the rear of the kiln for the insertion of the pyrometer thermocouple. See Figure 8.

The door cover, although optional, and not included in the original plans, was folded as indicated in the upper left-hand drawing of Figure 16, and was lined with insulation. Its installation is explained at the bottom of that figure.

<u>Door</u>. To give the door greater stability and better insulative quality, the door brick were laid flat. This change in horizontal dimension called for deeper and wider tongues and grooves, since these brick would receive more wear than the permanent side and rear wall brick. This extra dimension was especially important for the tongues. The bottom door brick were made one-quarter inch thinner, so that the top door brick, already made weaker by the cutting of its tapered edge, would not have to be made thinner to wedge under the roof support. A peep hole was

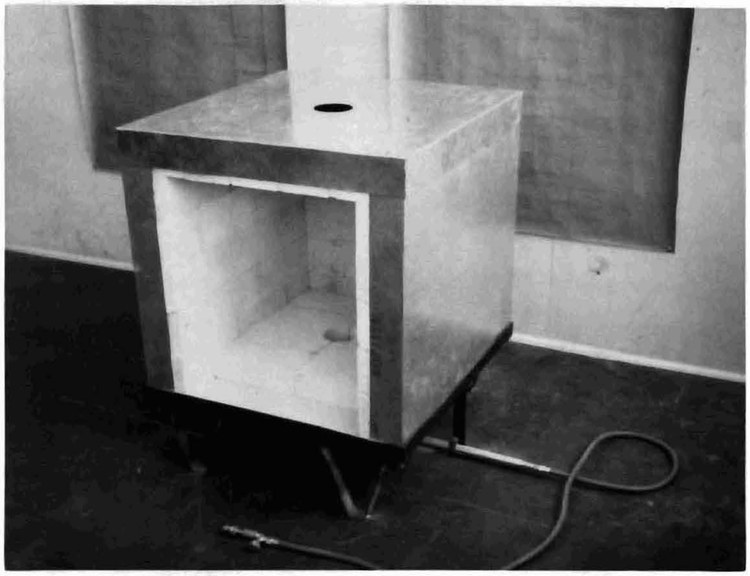


Figure 7. Shell, gas-fired kiln for home and student potters.

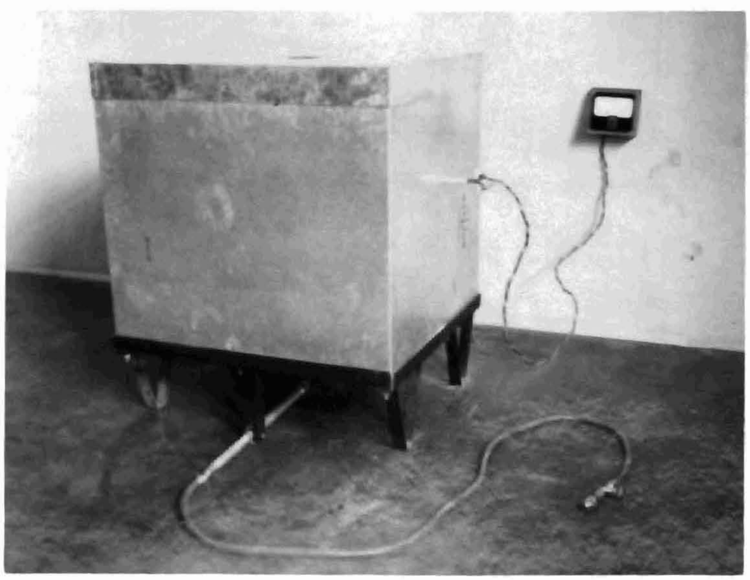


Figure 8. Pyrometer hole, gas-fired kiln for home and student potters.

centered at the point where four door brick met. The doorway was closed with each firing by stacking the door brick up until the next-to-top brick were in position. Then, at the top, the door wall was pulled outward enough to drop the last brick into their groove, and the leaning wall was shoved back under the roof support. It was hoped that the extra thickness of this wall would eliminate the need for a back-up material on the front side.

Flue and raincap. The flue used was a piece of stovepipe four feet long and four inches in diameter. Squeezed between the sides of the A-frame shelter, it needed no additional support, and was easily adjusted. See Figure 11. As mentioned previously, the aluminum raincap, shown in the figure, had to be replaced with one having greater heat resistance.

Shelter. The A-frame type shelter was constructed with four pieces of corrugated metal roofing, each six feet in length. Small holes were drilled, and bolts inserted, to tie the sheets together in pairs along a three-corrugation lap. Each double sheet was then further braced with a four-foot piece of two-by-four on the inside of the bottom end. These were attached with heavy screws. The two top ends were joined with five-inch bolts that were put through short two-by-four spacers at each end of the roof ridge.

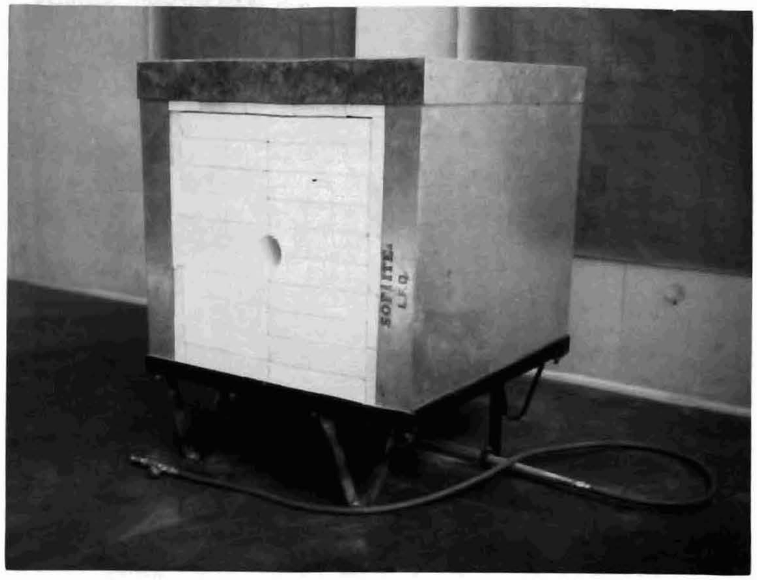


Figure 9. Door, gas-fired kiln for home and student potters.

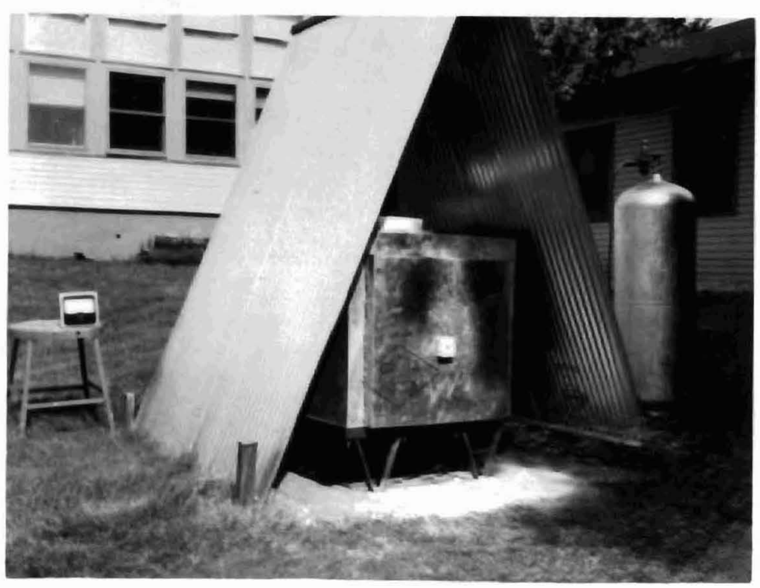


Figure 10. Door cover, gas-fired kiln for home and student potters.

See Figure 11. During the first firing, these two pieces were ignited by the intense heat at the flue. They were shortened two inches to prevent further damage. The shelter was installed over the kiln and secured with heavy wire to yard-long stakes, driven into the earth at the four corners of the base.

Damper. A damper was devised to further control the amount of reduction needed at various times during the firing cycle. The flue was raised approximately one inch above the top of the kiln, and two firebrick were shaped to fit like a collar around the flue hole. A groove, one and one-half inches wide, was cut along the inside bottom edge of each of these brick, allowing a small piece of asbestos board to be slid under the flue and collar from either side. With the use of asbestos gloves, this device was easily controlled. See Figure 11.

Figure 11. Shelter, gas-fired kiln for home and student potters.

Figure 12. Loading the kiln, gas-fired kiln for home and student potters.

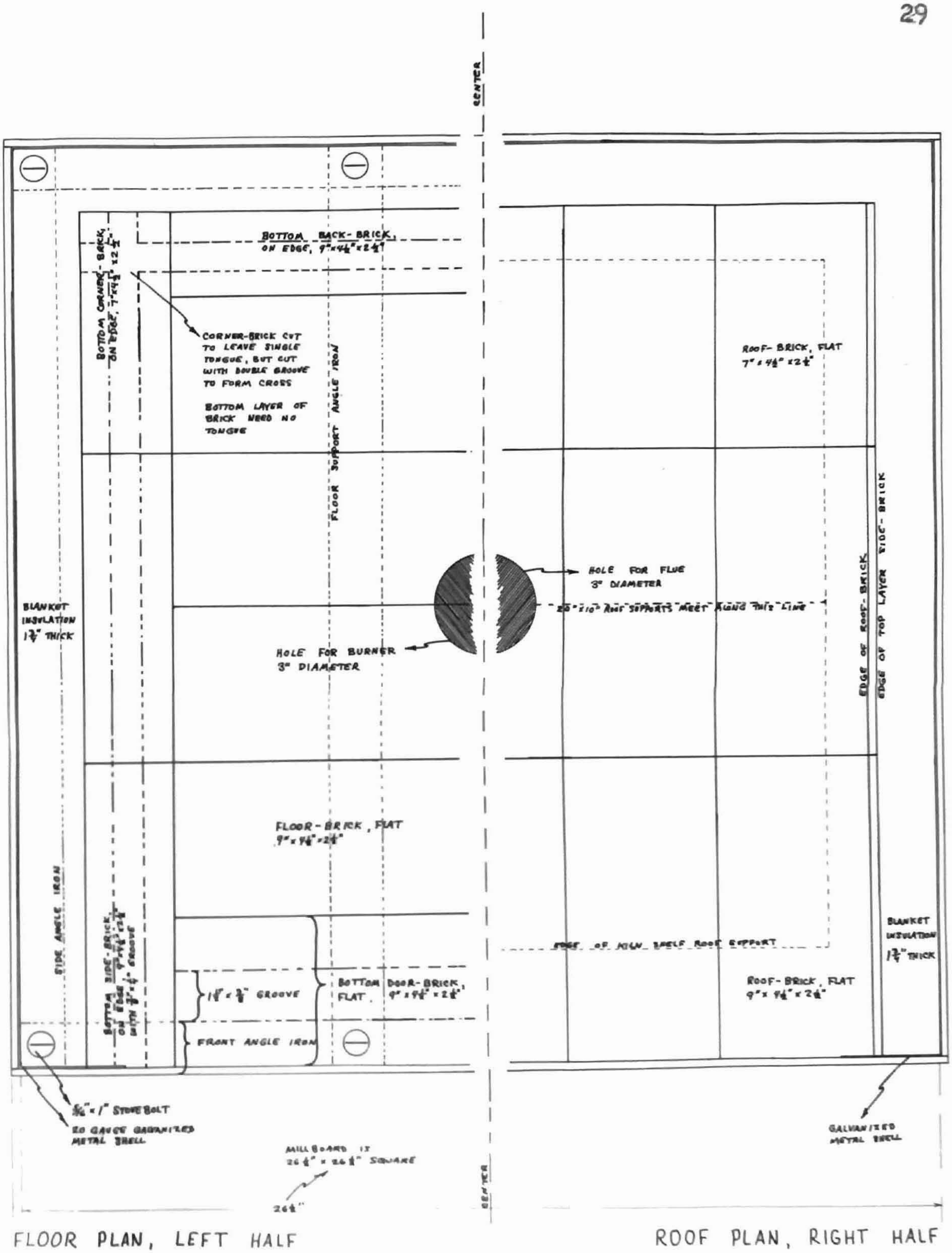
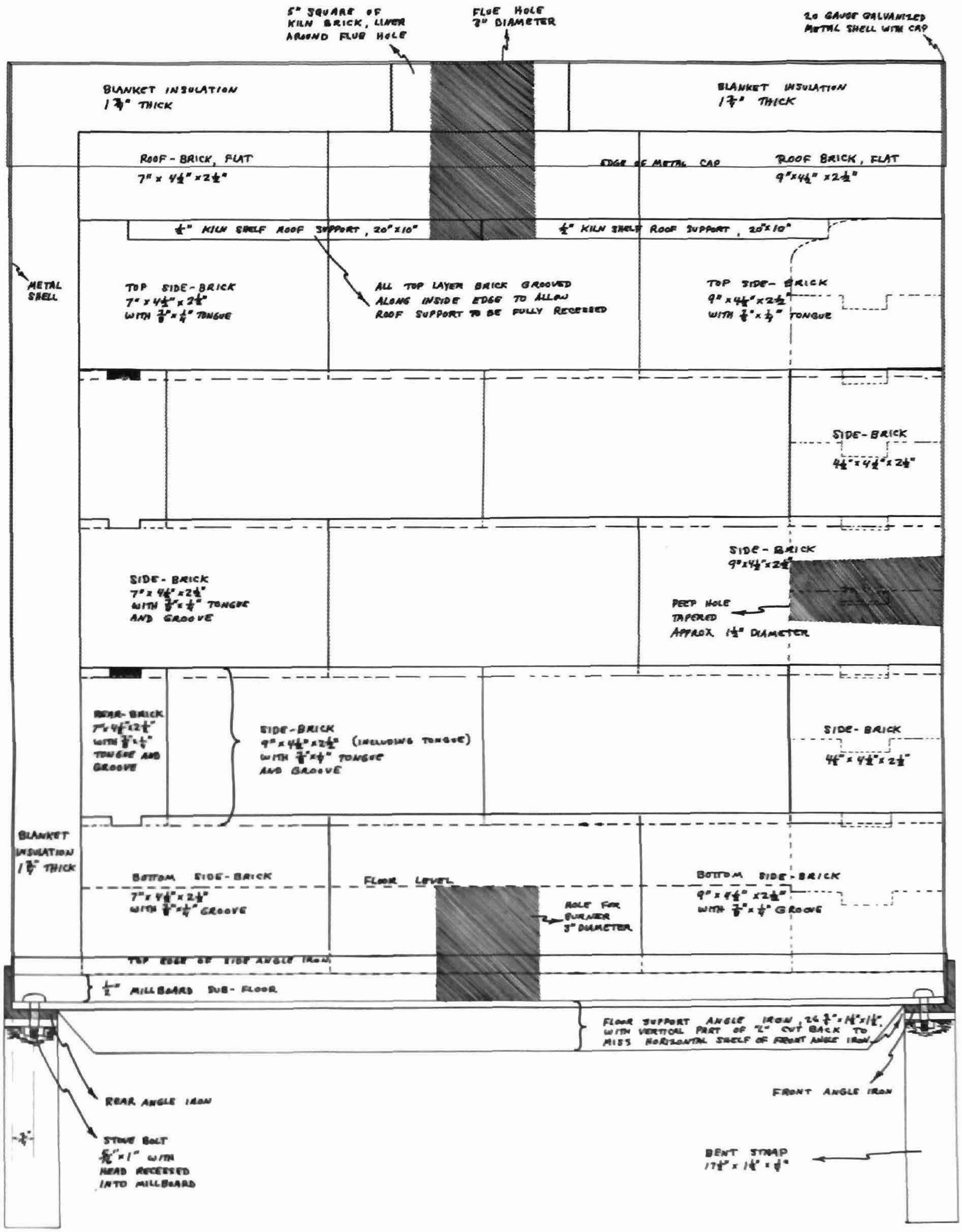
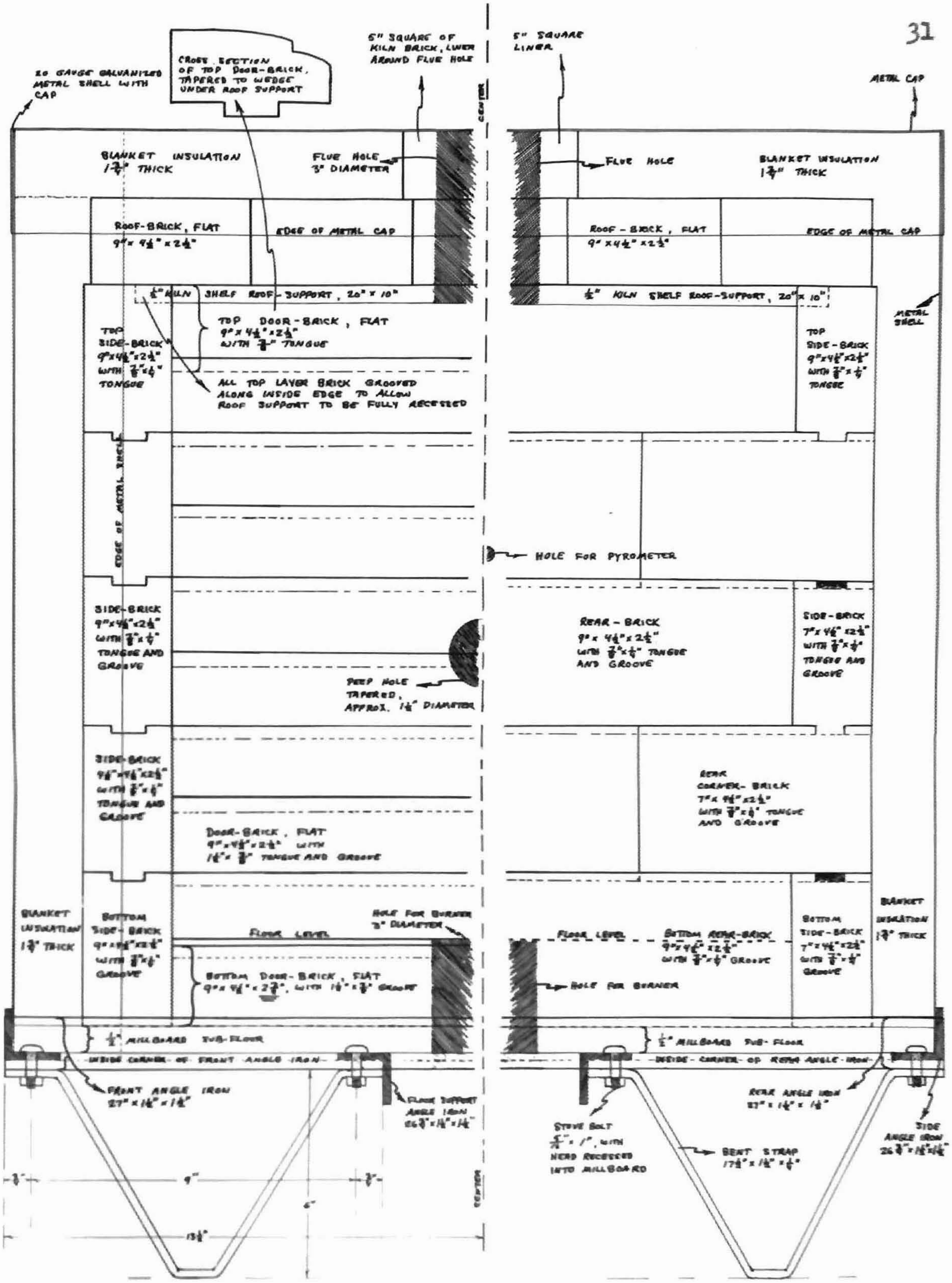


Figure 13. Specifications of floor and roof, gas-fired kiln for home and student potters.



SIDE VIEW

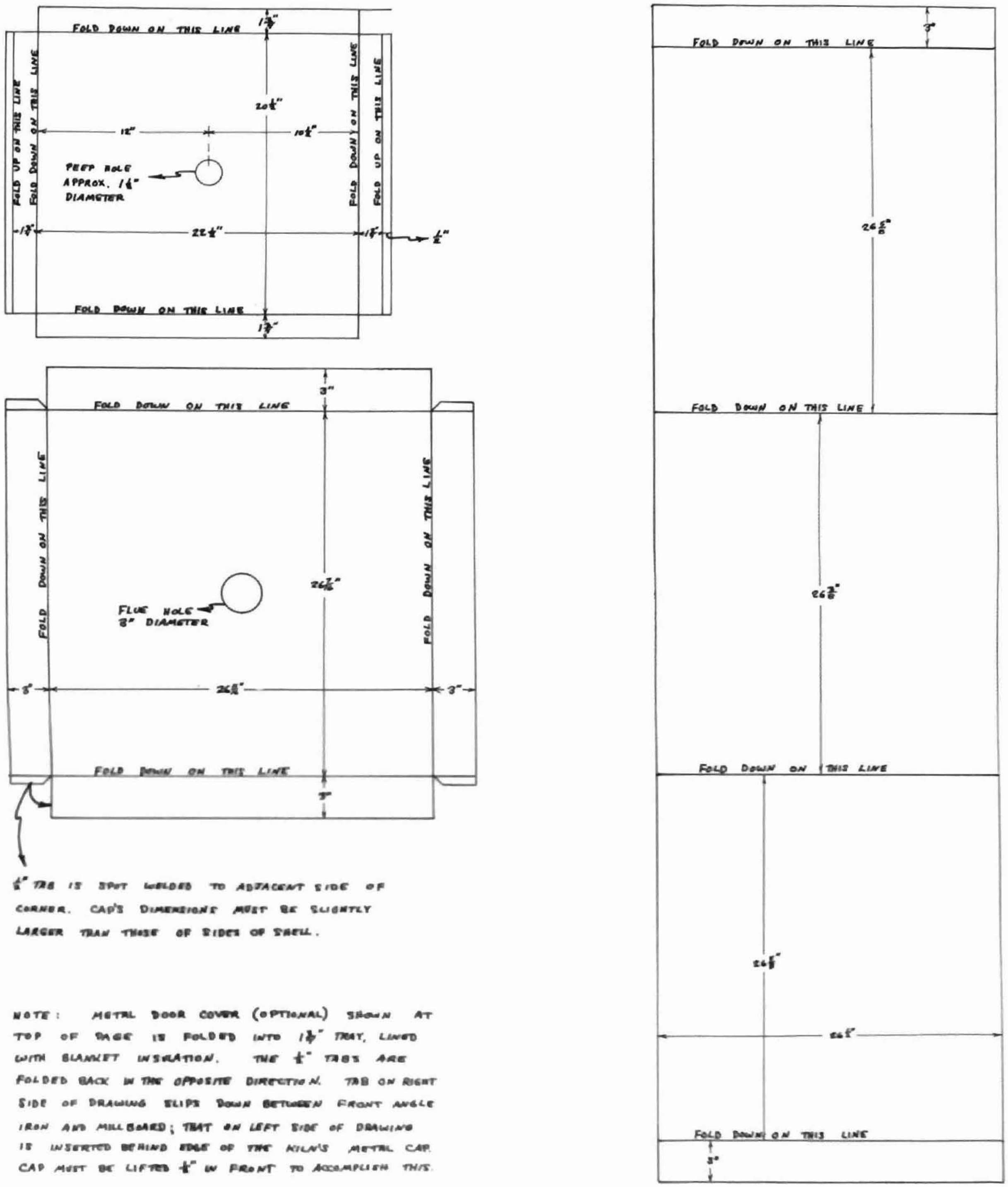
Figure 14. Specifications of side wall, gas-fired kiln for home and student potters.



FRONT VIEW. LEFT HALF

REAR VIEW. RIGHT HALF

Figure 15. Specifications of front and rear, gas-fired kiln for home and student potters.



METAL SHELL PARTS

Figure 16. Specifications of shell and door cover, gas-fired kiln for home and student potters.

CHAPTER IV

FIRING PROCEDURE

Preparations for a test firing were begun immediately after the construction was completed. The important facts and figures gathered, concerning reduction, were: (1) reduction should not be attempted before the kiln has reached a temperature of from 1200 to 1400 degrees, Fahrenheit, since blistering or bloating may result from the failure of carbon dioxide to escape before being trapped by the maturing body or glaze; (2) reduction should be started during the 1200 to 1400 degree range, so that carbon will be deposited in the pores of the clay before they are sealed off in the maturity of the body or glaze; (3) yellow flames at the spy hole indicate that reduction is occuring; (4) since reduction tends to slow or even stop the rate of temperature rise, it must in some cases be alternated with oxidation over periods of approximately one-half hour; and (5) reduction should continue until cones begin to fall, and although after this point, effect is negligible, it may be continued until the kiln is shut off.[1] This supplement to

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[1]Daniel Rhodes, Stoneware and Porcelain: The Art of High-fire Pottery (Philadelphia: Chilton Company, 1959) pp. 152-55.

the writer's knowledge and experience with oxidizing firing procedures was used as a guide during the first firing of the appliance.

First firing. A number of sets of pyrometric cones were distributed at three levels throughout the chamber to check for evenness of heat distribution. Cones eight, nine, and ten were used.

After the kiln was stacked, and while the door was still open, the burner was ignited and the action of the flame was observed. In a matter of minutes, a hot spot was noticed on the center of the bottom kiln shelf. As a corrective measure, a deflecting piece of light-weight firebrick was placed on two-inch stilts directly over the burner orifice. A second trial showed that this device spread the heat much more evenly over the bottom of the chamber. See Figure 11. The door was then closed, and the first firing was begun.

The temperature was recorded in ten-minute intervals, as shown in Figure 17. Gas pressure was held at approximately one pound during the first forty minutes, and then increased to four pounds. Since the pieces in the kiln were thoroughly dried before firing, the warm-up period was shortened somewhat. The temperature rose quite steadily to 1200 degrees, at which time reduction was begun by closing the damper approximately three-fourths of the way and by lowering the air shutter to within about one-eighth inch of the platform ring. Since this caused the temperature to rise more slowly, both damper and shutter were opened slightly, after about one-half hour of reduction. With an increase of gas pressure to seven pounds at the end of two and one-half hours, and up to ten pounds at the end of three hours, the temperature rose fairly evenly to 1900 degrees.

At this point it was noticed that the top of the flue raincap had collapsed, closing off the flue almost completely. A check of the peep hole showed that strong reduction was occurring, causing yellow flames to spurt out almost eight inches. After the raincap was pried off, the temperature climbed rather slowly to 2100 degrees. At this point, the number eight cone near the peep hole unexpectedly began to go over. The pressure was immediately lowered to seven pounds in order to slow down the last part of the cycle. Rhodes, among others, suggests a tapering off of the heat rise curve during the latter part of the firing cycle.[1] Within a few minutes, the number nine cone showed signs of weakening. The gas pressure was lowered to three pounds and left there throughout the soaking period. The kiln was shut

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[1] *Ibid.*, p. 154.

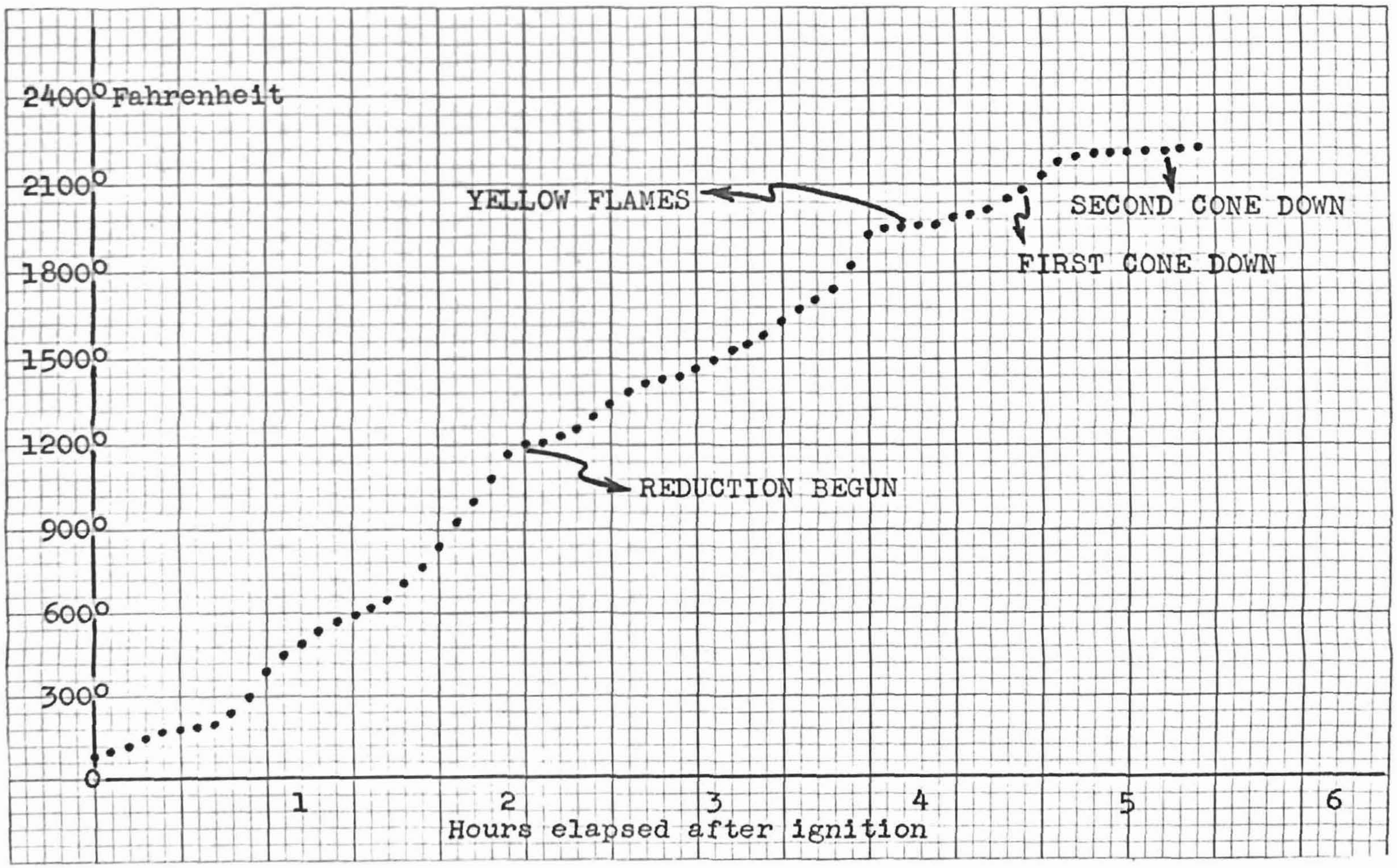

Figure 17. Firing cycle, first firing, gas-fired kiln for home and student potters.

off when the second cone was well down, five hours and twenty minutes after firing began.

It was then allowed to cool down to 1650 degrees, after which the chamber was tightly closed with pieces of asbestos board at the burner and flue holes. By the next morning, about fifteen hours after the closing of the chamber, the inside temperature had dropped to five hundred degrees. The top two door brick were removed. After a wait of about one-half hour, the temperature had dropped to about three hundred degrees, and the door was opened.

An examination of the cones throughout the kiln showed that the bottom of the chamber had been hotter than the top, and that the front had been hotter than the rear. This partially explained why the cones fell much earlier than expected. The number eight Orton standard pyrometric cone falls at a temperature of 2372 degrees, Fahrenheit. Since the pyrometer was at the rear of the kiln, and was inserted at a higher level than the cones visible through the peep hole, its thermocouple was in an area of the chamber that was not as hot, and consequently registered a lower temperature.

The fired test pieces definitely showed the effects of reduction. Although a copper red glaze and a celadon (soft grey-green) glaze were both somewhat lacking in color, the texture and brown flecked appearance of all the samples indicated that the reduction had been at times quite heavy.

Second firing. In an attempt to get more even heat distribution, the following adjustments were made previous to the second firing: (1) the deflecting brick was shaped into a cone, which widened the flame area at a lower level; (2) a small kiln shelf, eight inches square, was placed directly above the cone shaped brick to further direct the flames toward the walls of the chamber; and (3) the main bottom shelf was moved slightly closer to the front of the kiln, in the hope of directing more heat along the rear of the chamber.

Although the experience gained during the first firing made possible a more controlled rate of heat rise, the second firing cycle in most respects paralleled the first. The cones again fell earlier than expected, although, due to the previous warning, the rate of temperature change was somewhat slowed before the first cone fell. See Figure 18. Gas pressure adjustments were approximately the same as for the first firing, and the cooling procedure followed was the same. Test cones again indicated that the bottom and front of the chamber had been hotter than the top and rear areas, but the situation was somewhat improved over the previous trial. Test glaze results were also similar to those

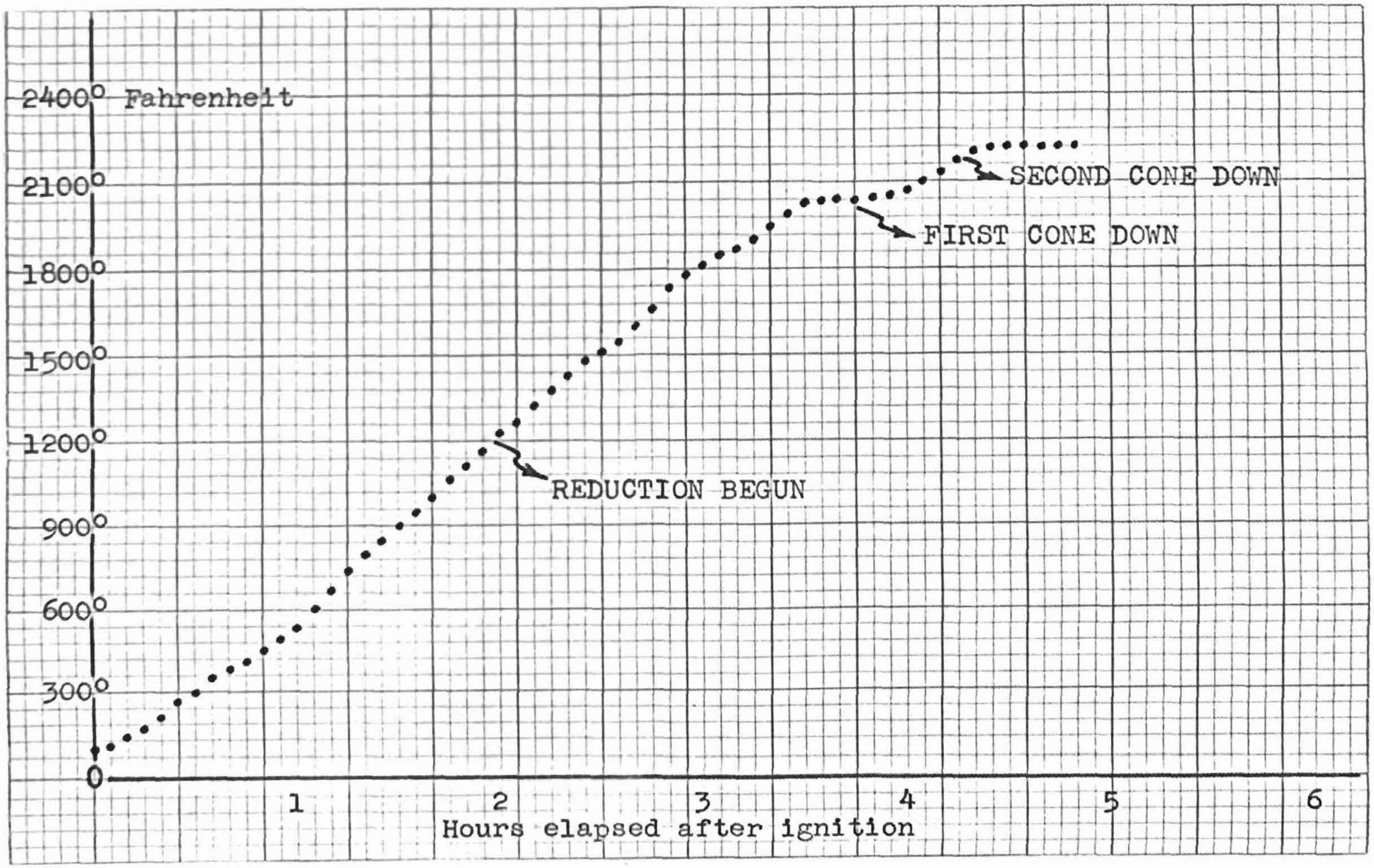

Figure 18. Firing cycle, second firing, gas-fired kiln for home and student potters.

obtained in the first firing, but indicated a somewhat less heavy reduction.

Third firing. An insulation-lined door cover was added to the unit in an attempt to even the temperature difference between the front and rear of the chamber. It was reasoned that a slightly greater amount of oxygen, entering through the door brick joints, could cause the flames to burn more efficiently on the front side of the kiln. No further attempt to lessen the temperature difference between the top and bottom of the unit was made, since the writer was advised that this is a common characteristic of gas-fired kilns, and is usually considered an advantageous one.[1]

As indicated in Figure 19, the third test firing began with a three-hour warm-up, operating on only one pound of gas pressure. At the end of this period, the temperature had risen to seven hundred degrees. An increase of pressure to two pounds resulted in a smooth rise in temperature until the beginning of reduction, after which the pressure was increased to four pounds. At the 1620 degree mark, some yellow flames were seen at the peep hole and a slight open-

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[1]Statement by William Ross at the Des Moines Art Center, Des Moines, Iowa, June 27, 1964, personal interview.

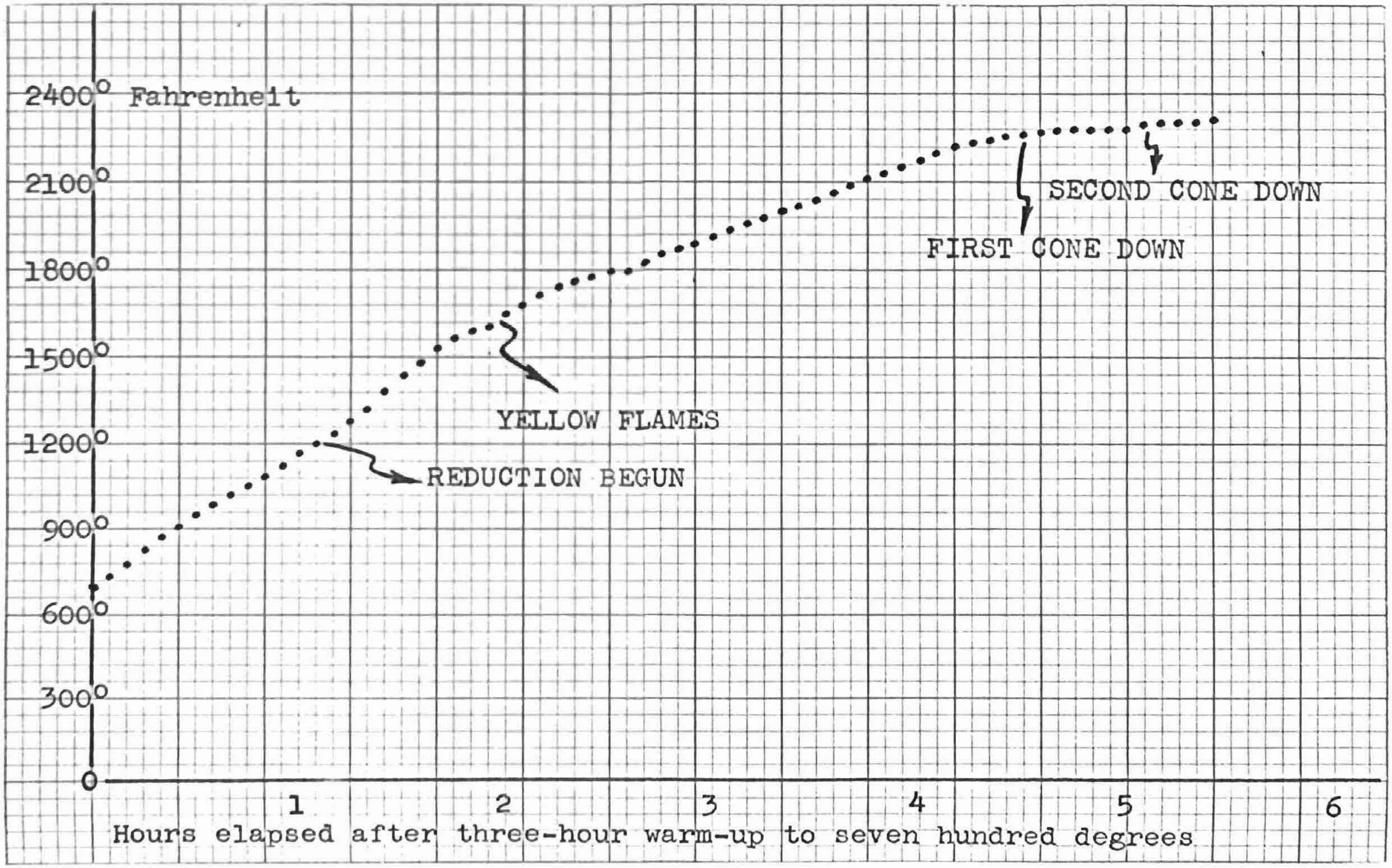

Figure 19. Firing cycle, third firing, gas-fired kiln for home and student potters.

ing of the damper was needed to keep the temperature climbing. During this firing, another factor explaining the difference between the heat indication of the cones and that of the pyrometer was discovered. The pyrometer indicator needle had a lag, which could be corrected by tapping or jarring the instrument. Figure 19 shows the effect on the recording of these temperatures, after such a correction was made at the 1600 and 1800 degree marks. After these experiments, the instrument was tapped with each recorded time interval. Other aspects of the firing were quite similar to the first two, with the exception that the recording showed a slightly higher final temperature, which allowed a longer firing time. Upon opening the kiln, it was found that the door cover had been effective for its purpose, although a very slight difference still remained. Carbon deposits again indicated that fairly heavy reduction had occurred.

CHAPTER V

CONCLUSIONS

The evaluation of the project was summarized by comparing the main facets of the problem set forth, with the accomplishments effective toward their solutions.

First, the kiln was to be low in cost, financially within the means of the average home potter or school's art budget.

The total cost of materials, shown in Chapter II, compares favorably with the cost of many small electric kilns, and is only a fraction of the cost of commercial gas-fired kilns of comparable size.[1]

Secondly, the kiln was to be easily adjusted or altered.

The tongue-and-groove type of construction used made complete disassembly of all kiln parts, and alterations thereof, a simple task. The chamber could also be adjusted in height by the addition of extra layers of wall and door brick.

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[1]Comparisons were made with price lists published by the following companies: (1) A. D. Alpine, Inc., 11837 Teale St., Culver City, California, (2) Denver Fire Clay Co., 3303 Blake St., Denver 17, Colorado, and (3) Western Ceramics Supply Co., 1601 Howard St., San Francisco 3, California.

Thirdly, the construction was to be simple enough to be accomplished in a home or school shop.

Most of the construction was done with ordinary hand tools. The electrical tools needed were ones to which the average person could easily find access.

Finally, the unit was to be capable of firing stoneware, and a goal of 2300 degrees was set for the top of the firing temperature range.

Although the unit was tested in only three firings, no sign of disintegration or damage of any kind was found, even after reaching temperatures of over 2400 degrees.

These comparisons show that the project was definitely a practical solution to the problem investigated. Undoubtedly, many other variations and even completely different types of kilns could have been made to fill the requirements set forth in this study.

Even though the kiln chamber is small, the uneven distribution of heat can be adjusted, or even, in some cases, taken advantage of. Further alteration may lessen this unevenness considerably. The compactness, neatness and portability of the completed kiln contribute much to its usefulness.

Plans have been made to use the kiln as an instructional device. It is hoped that, as a teacher, the writer will find it to be a means for broadening the student potter's experiences. Perhaps, for some, it will be an incentive to continue their inquiry into this limitless field of the unrecorded and untried mysteries of earth and fire.

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